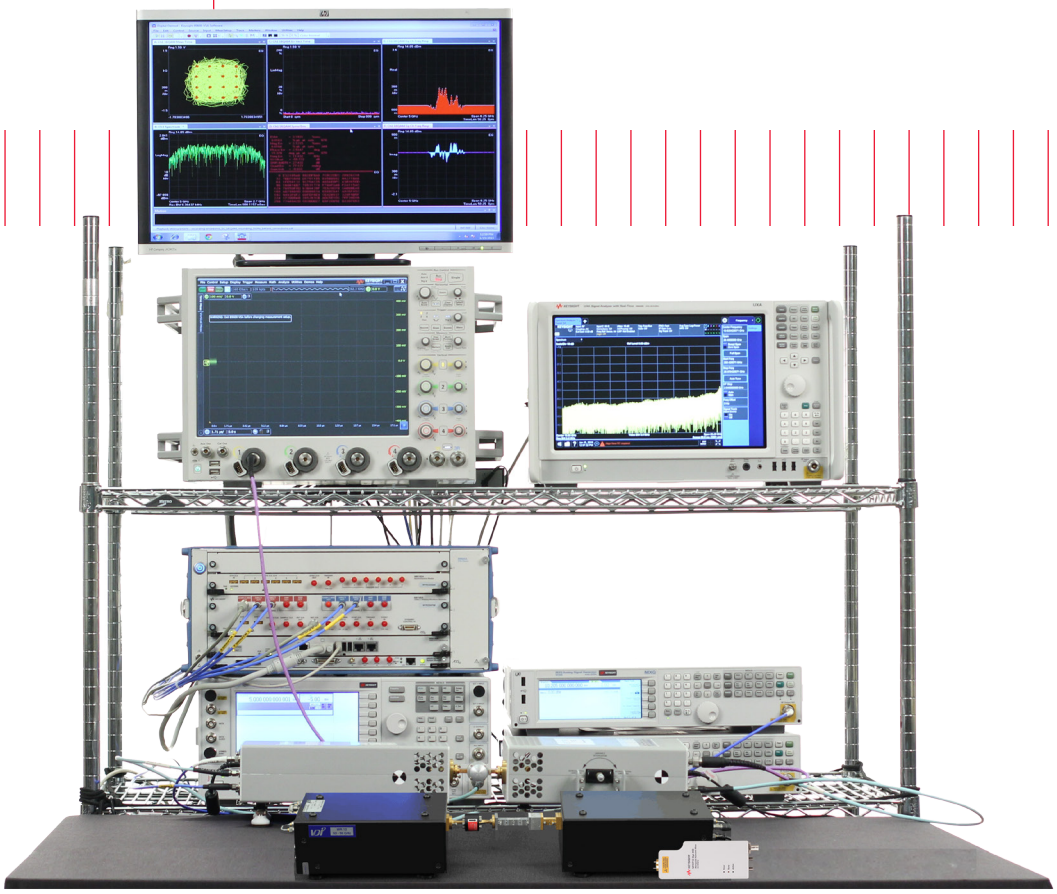
Keysight Technologies
5G Waveform Generation & Analysis Testbed, Reference Solution

Solution Brochure



KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Flexibility required for 5G research - waveform generation and analysis

Introduction

One of the biggest challenges faced by today's 5G researchers is the number and variety of waveforms, frequencies, and bandwidths being investigated. This includes waveforms at frequencies below 6 GHz, and at microwave and millimeter-wave frequencies which may involve wide bandwidths.

Because the 5G standardization process has not yet begun, physical-layer waveforms have not been defined. Several potential waveform candidates are in the running such as: filter bank multi-carrier (FBMC), orthogonal frequency-division multiplexing (OFDM), and universal filtered multi-carrier (UFMC). To address the multitude of possible scenarios, a flexible test environment is critical for this stage of 5G signal generation and analysis research.

5G Waveform Generation & Analysis Test Challenges

Flexibility is paramount at this early stage of 5G research. It enables "what if ?" analyses to be performed during evaluation of early concepts and potential 5G waveforms, using a variety of modulation schemes at many different frequencies and modulation bandwidths. The risk of potentially choosing the wrong path further reinforces the need for flexibility, especially in the form of signal creation and signal analysis tools that enable rapid changes in direction as strong waveform candidates emerge in the evolution of 5G.

As developers conduct experiments, a highly flexible testbed will enable them to evaluate proposed waveforms with prototype algorithms and hardware. It will also make it possible to quickly and easily transition between what-if scenarios in simulation and actual testing of the prototype algorithms and hardware.

More specifically, flexibility is needed in three key areas of 5G research and early testing:

- Generating and analyzing new candidate waveforms
- Supporting a wide range of modulation bandwidths, from several megahertz to a few gigahertz
- Supporting a wide range of frequency bands, from RF to microwave to millimeter-wave

5G Waveform Generation and Analysis Testbed, Reference Solution

To help address these test challenges, the 5G waveform generation and analysis testbed, Reference Solution combines hardware, software and measurement expertise providing the essential components of a flexible 5G waveform generation and analysis test platform. The Reference Solution enables engineers and researchers to generate and analyze emerging 5G candidate waveforms at RF, microwave, and millimeter-wave frequencies with modulation bandwidths of up to 2 GHz.

Combining 5G candidate and custom waveform signal creation software with two pieces of hardware—a precision AWG and a vector signal generator with wideband I/Q inputs—enables generation of wideband test signals with up to 2 GHz of modulation bandwidth at frequencies up to 44 GHz (and higher with upconverters). For signal demodulation and analysis, 89600 VSA software can be used either inside the simulation software, or on a signal analyzer, oscilloscope or PC controlling a variety of instruments or digitizers.

Figure 1 below shows a conceptual arrangement of the software and hardware elements and Figure 2 shows a combination of Keysight Technologies, Inc. hardware and software for a flexible 5G generation and analysis testbed.

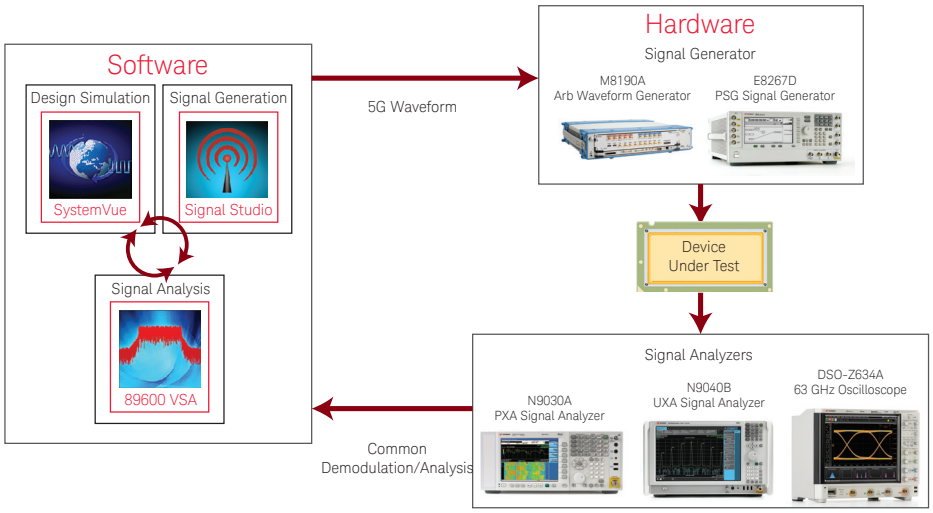


Figure 1. The 5G testbed provides combinations of hardware and software, giving the researcher flexibility needed to explore possible 5G technologies.

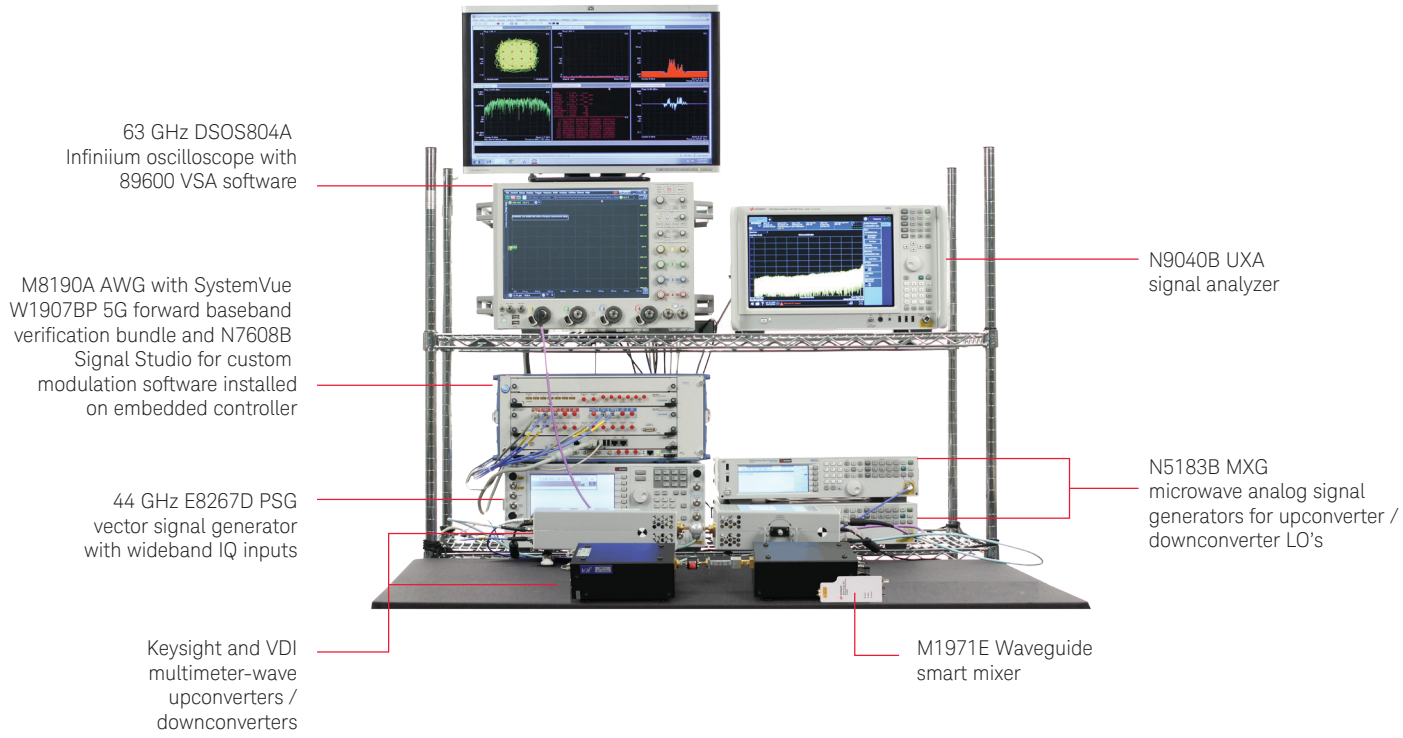


Figure 2. This combination of hardware and software provides a considerable amount of flexibility for the exploration of possible 5G technologies.

Features	Benefits
5G candidate waveforms	Evaluate new and legacy designs for emerging candidate waveforms- gain insight & reduce risk
Scalable modulation bandwidths and frequency bands	Provides flexibility to adapt as 5G evolves- reduce risk of choosing the wrong path
Supports many topologies for transmitter / receiver testing (IQ, IF, RF, microwave, millimeter-wave)	Evaluate performance at various stages along Tx and Rx chains- gain insight to debug issues

Reference Solution Configuration

Signal creation configuration

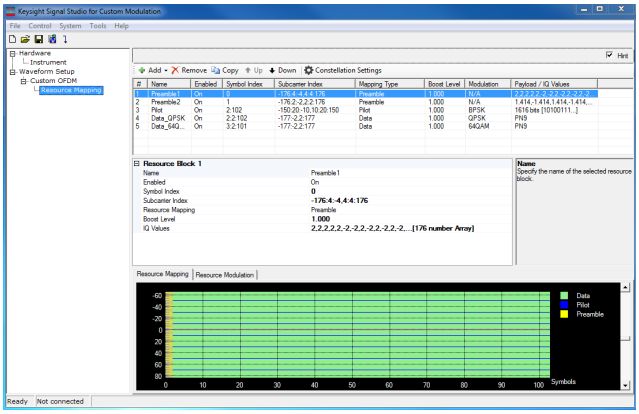
The testbed signal generation hardware includes the M8190A AXIe AWG installed in an AXIe chassis that also contains an embedded controller. Two software elements run on that controller: SystemVue with the W1907BP 5G forward baseband verification bundle and N7608B Signal Studio for custom modulation.

The 2-channel precision AWG can operate with 14-bit resolution at up to 8 GSa/s or 12-bit resolution up to 12 GSa/s. It offers 5 GHz of analog bandwidth and 2 GSa of memory per channel.

As part of the Reference Solution, the AWG is used to drive a PSG vector signal generator equipped with wideband differential external I/Q inputs (option 016). The wideband inputs can produce modulation bandwidths of up to 2 GHz on carrier signals up to 44 GHz. For signal generation above 44 GHz, upconverters are available from Keysight (58 to 64 GHz with N5152A) and Virginia Diodes, Inc. (60 to 90 GHz). MXG microwave analog signal generators provide the LOs for the millimeter-wave upconverters.

The SystemVue 5G forward baseband verification bundle enables 4G designers to move forward to 5G research. It supports the simulation of candidate 5G waveforms as well as custom OFDM and I/Q waveforms that can be used to evaluate custom or proprietary algorithms. Although SystemVue is primarily used for system design and algorithm development, it can also download waveforms to the AWG to bridge the gap between design and test phases.

Signal Studio for custom modulation is a flexible suite of signal creation tools with a parameterized graphical user interface (GUI) that makes it easy to create custom FBMC, I/Q and OFDM waveforms. Custom OFDM and custom I/Q VSA setup files can be saved for EVM testing using a variety of Keysight signal analyzers and oscilloscopes. Signal Studio can also be used to generate waveforms for the AWG and download waveforms to RF or microwave vector signal generators, such as the E8267D PSG, N5182B MXG and N5172B EXG.



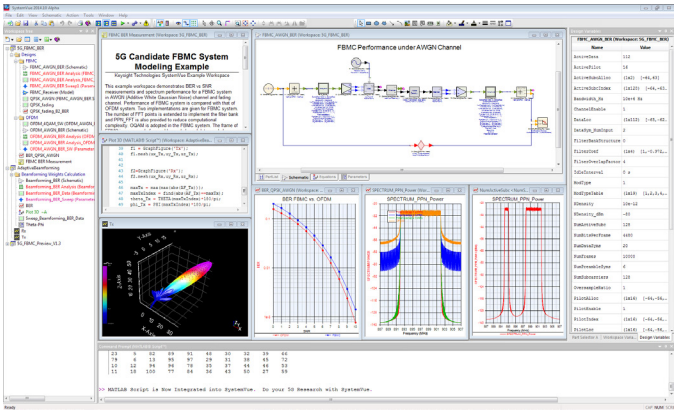
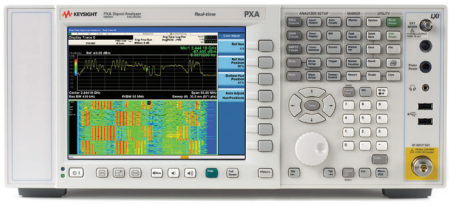


Figure 3. M8190A AXIe AWG, E8267D PSG, SystemVue 5G forward baseband verification bundle and Signal Studio custom modulation software.

Signal analysis configuration

The test signals can be analyzed using a signal analyzer and oscilloscope with 89600 VSA software. For higher frequencies from 60 to 90 GHz, a waveguide wideband smart mixer can be combined with the signal analyzer and oscilloscope.

89600 VSA software is a comprehensive set of tools for demodulation and vector signal analysis. The custom I/Q (option BHK) and custom OFDM (option BHF) demodulation analysis options are part of the Reference Solution. As noted above, it can be used with SystemVue, Keysight signal analyzers, oscilloscopes, and on a standalone PC connected to a variety of Keysight instruments to demodulate and characterize the performance of potential 5G waveforms.



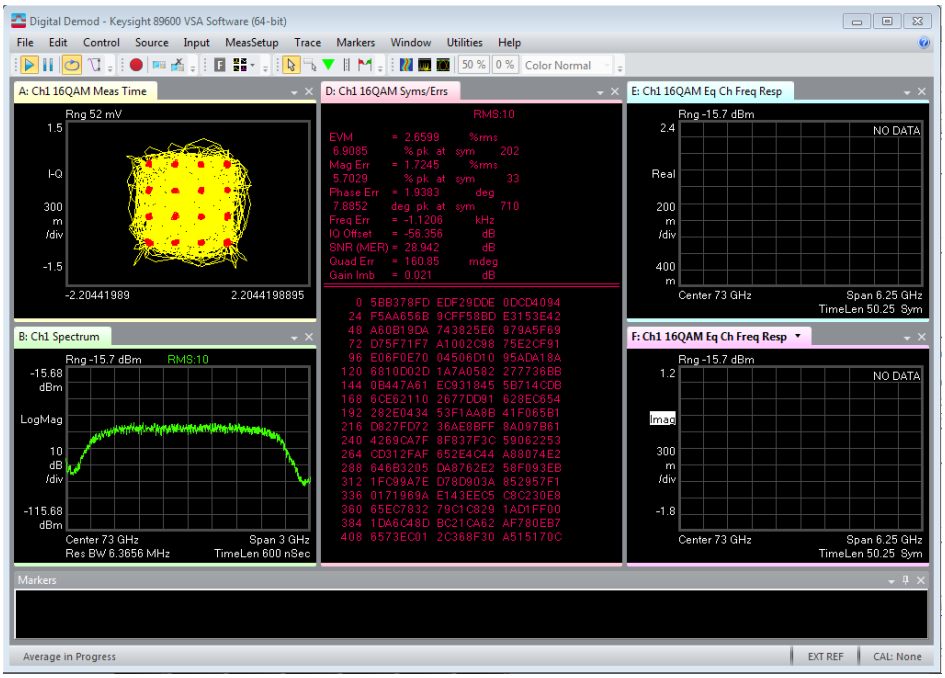


Figure 4. Wideband smart mixer, PXA signal analyzer, S-Series oscilloscope and 89600 VSA software.

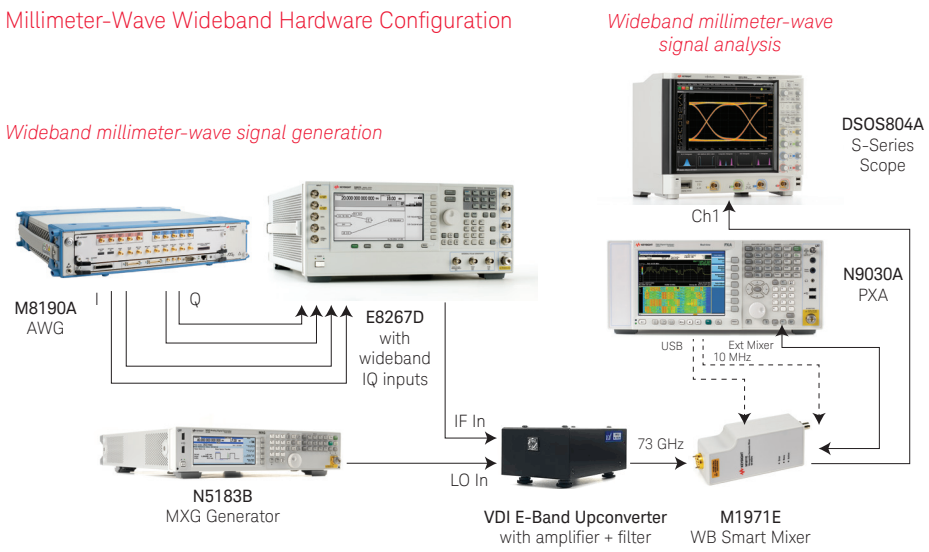


Figure 5. Example hardware configuration for millimeter-wave waveform generation and analysis at 73 GHz.

A simple block diagram of a 73 GHz configuration is shown in Figure 5 that can be used for 5G RF, microwave and millimeter-wave signal generation and analysis. The hardware configuration can be altered, to address the actual frequencies, bandwidths and waveforms of interest. Figure 5 includes the AWG and PSG setup previously described with the Virginia Diodes upconverter used to upconvert the signal to 73 GHz. The MXG provides the LO for the millimeter-wave upconverter and a VDI millimeter-wave amplifier and filter are used at the VDI upconverter output.

An M1971E wideband smart mixer is used for signal analysis from 60 to 90 GHz, when combined with an X-Series signal analyzer and S-Series oscilloscope. The wideband smart mixer is connected to the output of the VDI upconverter, and the IF output is fed into the X-Series signal analyzer. The auxiliary IF output is fed into the S-Series oscilloscope for demodulation analysis with 89600 VSA software.

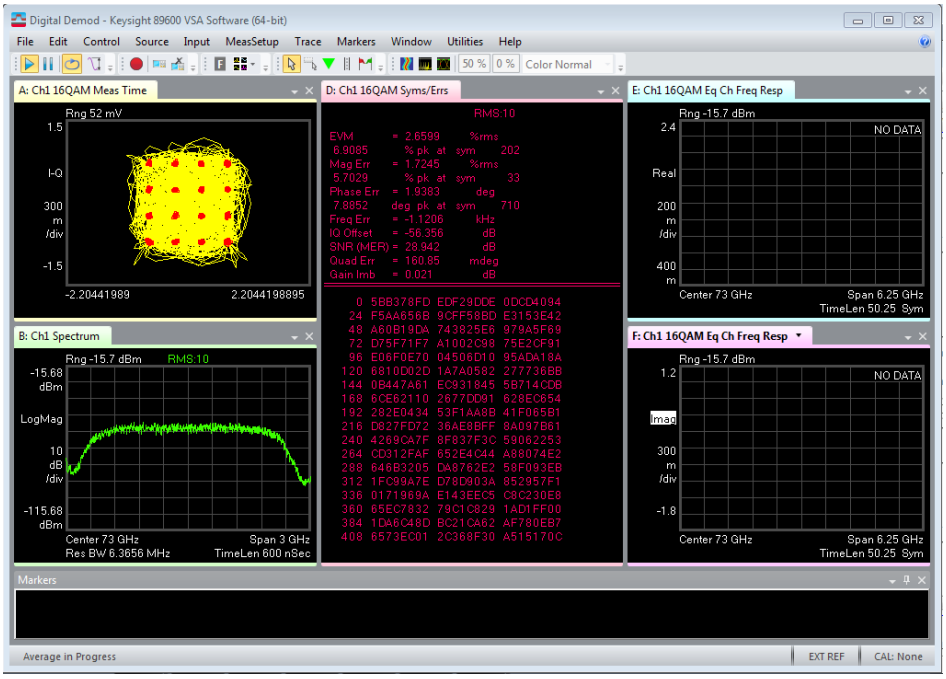


Figure 6. Demodulation of a 73 GHz waveform with 2 GHz of modulation bandwidth

Figure 6 shows the demodulation analysis of a vector-corrected waveform at 73 GHz with 2 GHz of modulation bandwidth, using 89600 VSA software. Demodulating a 2 GHz wideband signal is typically quite difficult without adaptive equalization due to hardware impairments across the wide bandwidth. However, in this example the linear amplitude and phase errors were corrected during simulation to generate a corrected waveform that produced a low EVM without adaptive equalization.

This 73 GHz example configuration is one of many possible configurations. Other configurations can be created to address different frequencies and bandwidths as shown in Table 1. A Keysight representative can recommend the best hardware configuration for your specific application requirements.

Carrier Frequency	Modulation Bandwidth	Source Configuration	Analyzer Configuration
< 6 GHz	< 160 MHz	MXG	X-Series Analyzer (MXA, PXA, UXA)
< 44 GHz	< 1 GHz	AWG + PSG	PXA + S-Series Oscilloscope
60 to 90 GHz	< 2 GHz	AWG + PSG + VDI Millimeter-Wave Upconverter	Wideband Smart Mixer + PXA + S-Series Oscilloscope

Table 1. General overview of source and analyzer configurations for different carrier frequencies and modulation bandwidths

Reference Solution Key Performance Characteristics

M8190A AXIe 12 GS/s arbitrary waveform generator
14-bit resolution up to 8 GSa/s or 12-bit resolution up to 12 GSa/s
Analog bandwidth 5 GHz (direct DAC out)
Up to 2 GSa arbitrary waveform memory per channel
E8267D PSG vector signal generator
100 kHz to 20, 31.8, or 44 GHz. Extendable to 60-90 GHz (and other frequency bands) with VDI millimeter-wave upconverter
+ 14 dBm at 20 GHz (typical) + 13 dBm at 40 GHz (typical)
External I/Q inputs provide up to 2 GHz modulation bandwidth when used with M8190A AXIe AWG
N5183B MXG microwave analog signal generator for uW LO
9 kHz to 13, 20 31.8 or 40 GHz
+ 15 dBm output power at 20 GHz
-124 dBc/Hz phase noise at 10 GHz and 10 kHz offset
N9029AV12-UDC Millimeter-wave upconverter /downconverter
60 to 90 GHz frequency range
M1971E Waveguide wideband smart mixer
55, 60 to 90 GHz
27 dB maximum conversion loss
N9030A PXA signal analyzer **(a UXA may also be used depending on application requirements)**
3 Hz to 3.6, 8.4, 13.6, 26.5, 43, 44, or 50 GHz
10 MHz (standard), 25, 40, 85, or 160 MHz analysis bandwidth
+22 dBm third order intercept (TOI)
DSOS804A S-Series oscilloscope
8 GHz bandwidth with flat frequency response for high signal fidelity
20 GSa/s maximum sample rate
10-bit analog-to-digital converter (ADC) vertical resolution

Hardware Elements

The combination of this test equipment provides waveform generation and analysis up to millimeter-wave frequencies with up to 2 GHz of modulation bandwidth. A Keysight representative can help to recommend the best hardware configuration based on the specific application needs.

M8190A AXIe 12 GS/s arbitrary waveform generator

www.keysight.com/find/m8190a

The M8190A AWG is used to drive an E8267D PSG vector signal generator equipped with wideband external I/Q inputs (option 016) to produce modulation bandwidths of up to 2 GHz on carrier signals up to 44 GHz. The M8190A is a 2-channel precision AWG that can operate with 14-bit resolution at up to 8 GSa/s or 12-bit resolution up to 12 GSa/s. It has 5 GHz of analog bandwidth and 2 GSa of memory per channel.

E8267D PSG vector signal generator

www.keysight.com/find/e8267d

The E8267D PSG vector signal generator provides wide-band signal generation to 44 GHz The PSG includes wideband differential external I/Q inputs for modulation bandwidths up to 2 GHz. For signal generation above 44 GHz, upconverters are available from Keysight (58 to 64 GHz with N5152A) and Virginia Diodes Inc. (60 to 90 GHz). MXG microwave analog signal generators (N5183B) are used to provide the LOs for the millimeter-wave upconverters.

N5183B MXG microwave analog signal generator

www.keysight.com/find/n5183b

N5183B MXG microwave analog signal generators are used to provide LOs for the millimeter-wave upconverters and downconverters.

N9029AV12-UDC Millimeter-wave upconverter / downconverter*

www.keysight.com/find/SA_mmwave

The N9029AV12 millimeter-wave signal analyzer frequency extension module is one of the mixer/amplifier/multiplier chain series (WRxx SAX series) from VDI Inc. Option UDC enables it to be used as a millimeter-wave upconverter to upconvert the E8267D PSG vector signal generator output up to 60 to 90 GHz. It can also be re-configured as a downconverter, designed to work directly with the X-Series signal analyzers.

*Note: Other frequency bands may be available, depending on the application. VDI VDI12.0AMP amplifier and WR12BPF71-76 filter are not shown. Please contact VDI for further information (www.vadiodes.com).

Hardware Elements (continued)

M1971E Waveguide harmonic smart mixer

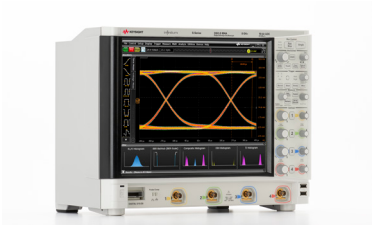
www.keysight.com/find/smartmixer

The M1971E wideband smart mixer is combined with an X-Series signal analyzer, such as an N9030A PXA signal analyzer, and DSOS804A S-series oscilloscope for wideband signal analysis from 60 to 90 GHz. The M1971E 55, 60 to 90 GHz waveguide harmonic mixer is an un-preselected mixer for wideband millimeter-wave signal analysis of more than 2 GHz with X-Series signal analyzers.

N9030A PXA signal analyzer

www.keysight.com/find/n9030a

A Keysight N9030A PXA signal analyzer is used for spectrum and demodulation analysis. The PXA signal analyzer, a high-performance member of the X-Series, provides frequency coverage up to 50 GHz, and ensures present and future flexibility through optional measurement capabilities and hardware expandability. A UXA may also be used, depending on application requirements.



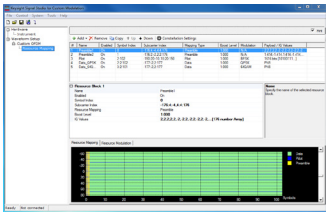
DSOS804A Oscilloscope

www.keysight.com/find/oscilloscopes

An Infiniium S-Series high-definition oscilloscope is used to perform wideband demodulation analysis when paired with the N9030A PXA signal analyzer used as a wideband downconverter and the M1971E wavegude harmonic smart mixer. A 10-bit ADC, low-noise front end, correction filters, vertical scaling support down to 2 mV/division, and a precise time base produce high-fidelity measurements. In addition, its advanced frame and broad range of capability enable the S-Series oscilloscopes to tackle a wide range of test needs.

Software Elements

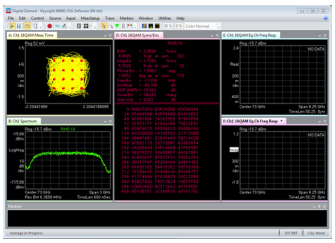
The combination of this signal generation and analysis software provides waveform generation and analysis of candidate 5G waveforms with the hardware configuration listed above.



N7608B Signal Studio for custom modulation

www.keysight.com/find/n7608b

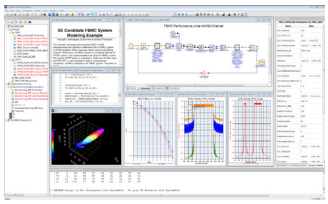
N7608B Signal Studio for custom modulation is a flexible suite of signal-creation tools that will reduce the time you spend on signal simulation. Custom FBMC, OFDM, and IQ signals can quickly and easily be generated for component, transmitter, and receiver test of emerging 5G applications.



89601B 89600 VSA Software

www.keysight.com/find/89600

The 89600 VSA software is a comprehensive set of tools for demodulation and vector signal analysis. These tools enable you to explore virtually every facet of a signal and optimize your most advanced designs. As you assess the tradeoffs, the 89600 VSA helps you see through the complexity.



W1461BP SystemVue with W1907BP 5G forward baseband verification bundle

www.keysight.com/find/systemvue

The SystemVue W1907BP 5G forward baseband verification bundle enables 4G designers to start anticipating 5G challenges today, and continue forward into the final 5G standard, using a single configuration. It combines existing 4G references for LTE-Advanced (W1918) and 3D WINNER+ MIMO channel modeling (W1715), backward support for older 2G/3G standards (W1916), and then adds forward-looking references for 5G PHY candidates, beginning with a full transmit/receive reference for Filter Bank Multi-Carrier (FBMC). The 5G simulation models within the W1907BP library bundle offer compiled versions of the W1906BEL 5G source code models.

Recommended Reference Solution Base Configuration

This Reference Solution is flexible and scalable. Buy what you need today and add more capabilities as the 5G measurement requirements evolve.

The following is a summary of the 5G waveform generation and analysis base configuration. This configuration is designed for RF modulation bandwidths less than 1 GHz and frequency bands between 100 kHz and 44 GHz. This is a minimum configuration and additional test equipment and/or options may be needed based on the specific application requirements.

Note that other configurations may be available depending on specific application requirements. Since 5G is not yet well-defined, the best hardware configuration for a specific application depends on the actual frequencies, bandwidths and waveforms of interest. A Keysight representative can recommend the best hardware configuration based on the specific application requirements.

Model	Description
M8190A	**AXIe AWG**
M8190A-002	AWG – 2-channels
M8190A-02G (qty:2)	128 MSa to 2 GSa memory/Ch
M8190A-14B	14-bit resolution
M8190A-12G	12-bit resolution
M8190A-BU1	Bundle 1 (5-slot chassis and controller)
M8190A-DUC	Digital upconversion
M8190A- AMP	AC and DC amplifier
M8190A-811(x4)	Cable assembly
E8267D	**PSG Vector Signal Generator**
E8267D-544	Frequency range, 250 kHz to 44 GHz
E8267D-016	IQ differential inputs
E8267D-H18	Wideband modulation < 3.2 GHz
E8267D-UNY	Enhanced ultra-low phase noise
E8267D-602	Internal baseband generator
N9030A*	**PXA X-Series Signal Analyzer**
N9030A-544	Frequency range, 3 Hz to 44 GHz
N9030A-B1X	Analysis bandwidth, 160 MHz
N9030A- LNP	Low noise path
N9030A-P44	Preamplifier 44 GHz
N9030A- EXM	External mixing
N9030A-CR3	CR3 connector rear, wideband IF output
N9030A-MPB	Microwave preselector bypass
DSOS804A*	**S-Series High-definition Oscilloscope, 8 GHz**
DSOS000-400	Memory- 400 Mpts/ch

**Note: A high performance oscilloscope such as a DSAZ504A or DSAZ634A may also be used for high frequency wide bandwidth measurements (e.g. 2 GHz modulation bandwidth). Please consult with a Keysight representative for more information.*

Recommended Reference Solution Base Configuration (continued)

Software	
N7608B	**Signal Studio for Custom Modulation**
N7608B-AFP	Connect to M8190A AWG
N7608B-EFP	Custom IQ
N7608B-FFP	Custom OFDM
N7608B-GFP	Custom 5G
89601B	**89600 VSA Software**
89601B-200	Basic vector signal analysis and hardware connectivityCustom OFDM modulation analysis
89601B-BHF	Digital modulation analysis
89601B-AYA	Custom IQ modulation analysis
89601B-BHK	(requires AYA)
W1461BP	**SystemVue Comms Architect (Recommended, optional)**
W1907BP	**SystemVue 5G Forward Baseband Verification Bundle (Recommended, optional)**

Extended Configuration for 60 to 90 GHz and up to 2 GHz of Bandwidth

The following is a summary of the additional equipment needed to extend the base configuration for RF modulation bandwidths up to 2 GHz between 60 to 90 GHz. The test equipment configuration may vary depending on the frequency mixing scheme (e.g. LO frequencies required). This is a minimum configuration and additional test equipment and/or options may be needed, based on the specific application requirements.

Model	Description
N5183B	**MXG X-Series Signal Generator (used for upconverter LO)**
N5183B-520 N5183B-UNY	Frequency range, 9 kHz to 20 GHz Enhanced low phase noise
N9029AV12-UDC*	**Millimeter-wave Upconverter / Downconverter**
M1971E	**Waveguide Smart Mixer**
M1971E-001	60 to 90 GHz

**Note: N9029AV12-UDC can also be configured as a downconverter. If the N9029AV12-UDC is used instead of the M1971E waveguide smart mixer, then an additional N5183B MXG is recommended for the downconverter LO. Additional hardware may also be required if the N9029AV12-UDC is used as an upconverter, such as the Virginia Diodes, Inc. VDI12.0AMP amplifier and WR12BPF71-76 filter for 73 GHz applications This additional hardware depends on application requirements and are not listed here. Please contact VDI for further information.*

Hardware Support and Warranty

Keysight provides its standard warranty on all hardware products. The warranty service provides standard coverage for the country where product is used, including:

- All parts and labor necessary to return to full specified performance
- Recalibration for products supplied originally with a calibration certificate
- Return shipment

Standard hardware warranty includes 3 year warranty on each product with a typical turn-around time of 15 days.

Keysight has optional upgraded warranty services on each product including:

- Extended warranty from 3 years to 5 years
- Express warranty for faster turnaround time. Available upgrade for 3 and 5 year warranties.

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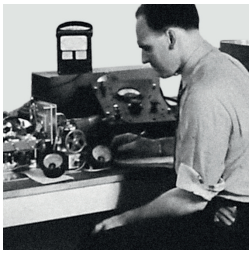

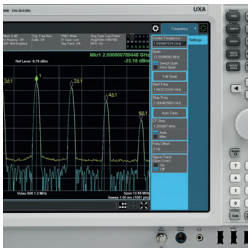

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Published in USA, August 27, 2015
5992-1030EN
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